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Using Citizen Science to Quantify Community Garden Crop Yields

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New York City is home to over 500 community gardens, over 80% of which host food production (GrowNYC 2010). This paper is a case study of Farming Concrete, an open, community-based study aimed to define community gardens in the context of the New York City food system and to educate local communities about developing and conducting meaningful research. The project employs citizen science methods in which the gardeners and researchers alike are involved in the design and implementation processes. This paper will outline the methods and challenges involved in conducting participatory urban agriculture research, as well as discuss findings regarding how much food was grown in NYC community gardens in 2010 and 2011.

Keywords

urban gardening, community garden, urban agriculture, citizen science, metrics, New York City

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INTRODUCTION

Community gardens, particularly in urban areas, have long been understood in the context of the social and environmental benefits they bring to a neighborhood (Been and Voicu 2006). They are home to important biodiversity, host outdoor events both public and private, partner with nearby schools to provide educational experiences, and offer intergenerational, intercultural recreational activities (Gittleman et al. 2010). Community gardens also often involve food production and contribute to local food security, defined as "access by all people at all times to enough food for an active, healthy life" (Coleman-Jensen et al. 2011). New York City is home to over 500 community gardens, over 80% of which host food production (GrowNYC 2010). While the types of plants cultivated in these spaces is largely known, the quantity of food produced in them remains unknown. Farming Concrete is a project utilizing citizen science strategies to measure the amount of food produced in community gardens in New York City. Farming Concrete's citizen science approach makes it methodologically different from other attempts to estimate urban food production (BNAN 2009; Vitiello and Nairn 2009; Ackerman 2011). This paper will explore the methods, challenges, and successes of quantifying food production in community gardens.

Urban Agriculture and Community Gardens

Urban agriculture is the practice of producing food within a city boundary or on the immediate periphery of a city. It includes the cultivation of vegetables, herbs, fruit, and flowers. It can also consist of orchards, parks, forestry, firewood, livestock, aquaculture, and bee-keeping (Egziabher 1994). This paper looks specifically at the agricultural activities that take place in community gardens. The phrase "community garden" has been defined in many ways, including "a neighborhood garden in which individuals have their own plots, yet share in the garden's overall management" (Lawson 2005), or simply "any piece of land gardened by a group of people" (American Community Garden Association 2011). This differs from the broader "urban garden," which can include other types of programs such as school gardens, relief gardens, children's gardens, entrepreneurial job-training gardens, horticultural therapy gardens, company gardens, demonstration gardens, and more (Lawson 2005). Farming Concrete uses a combination of these definitions – gardens that are open to the public and maintained by individuals within the community. As the project grew, many school gardens and gardens managed by private institutions requested to participate. The scope of Farming Concrete was broadened to include these types of gardens in Year 2 (2011). Backyard gardeners also showed interest in the project, and although they were not formally included in the study, they had access to free PDF forms made available for download on Farming Concrete's website (Farming Concrete 2011).

The contemporary community gardening movement began in the late 1960s and early 1970s, when urban decline and disinvestment, particularly in poor neighborhoods of color, brought about renewed interest in urban green spaces (Saldivar-Tanaka and Krasny 2004). The economic boom of the 1990s led to increased demand for housing and commercial development in cities. Despite occupying their lots for years, and in some cases decades, community gardeners lacked secure land tenure and their gardens were seen as obvious sites for development (Saldivar-Tanaka and Krasny 2004). Trouble for the gardens in New York City began brewing in 1998, when Mayor Rudolph W. Giuliani placed all community gardens, over 700 in number, up

for disposition to private interests (NYC Community Garden Coalition 2010). An agreement was reached in 2002 that protected hundreds of gardens for a period of time, but land tenure remains an important issue for community gardeners today. Many stakeholders feel that thorough documentation of all aspects of community gardening will aid in advocacy for preservation.

Farming Concrete's goal of quantifying food production in New York City's community gardens was a product of both the political climate in 2010 and the general need for better data about the city's gardens. During this first year of the project, community gardens on public land were confronted with the possibility of changing legal status, as the 2002 community garden agreement between the City of New York and the New York State Attorney General's Office was set to expire and new Community Garden Rules were being drafted. The need for more data on the city's community gardens was understood by government officials, policy makers, gardeners, and activists alike, and so the design and implementation of the Farming Concrete project involved a variety of stakeholders from its inception.

Citizen Science

The general public is not often considered a knowledge-maker in the eyes of the scientific community (Fischer 2000). The exclusion of those outside the realm of professional scientific research from the knowledge-making process can lead to gaps in academic literature. It can also lead to a disempowering and exploitative relationship between researchers and the communities they study as data is taken from communities and put in an inaccessible place such as an academic journal. Citizen science attempts to make the knowledge-making process of a science more democratic by giving a community some degree of decision-making power over what is studied, how it is studied, the collection of data, and the conclusions drawn from the research (McCormick 2009).

One example of citizen science is related by Jason Corburn in his book *Street Science* (2005). A group of residents in the Greenpoint and Williamsburg neighborhoods of Brooklyn, New York, worked with the Environmental Protection Agency (EPA) to conduct an urban food system assessment. The community urged the EPA officials to expand their assessment to include individuals fishing in nearby Newtown Creek, which is now a Superfund site (US Environmental Protection Agency 2011). The EPA gave the community some influence over study design and data collection by working with the residents to develop and conduct a survey of the fishermen in addition to the original food system assessment

There are as many ways to perform citizen science as there are communities. Another approach to citizen science is a model developed in the Netherlands called "science shop". Science shop gives a community influence over the target of research by allowing the community to use "knowledge-producing institutions" such as universities as consultants to answer their questions (Cooper et al. 2007). Open source technology is increasingly being used to make data collection, analysis, and visualization possible outside of research institutions, and groups like the Public Laboratory for Open Technology and Science (PLOTS) are emerging around these technologies. PLOTS focuses on what it calls "civic science," which includes experimentation with open source hardware and software to generate knowledge and share data

about community environmental health (Public Laboratory for Open Technology and Science 2011).

In order to maximize the effectiveness of the data collected, Farming Concrete incorporated citizen science principles into the project's design, data collection methods, and technological infrastructure. The method of measuring food production was developed through a series of informal conversations with community gardeners, staff from GreenThumb (NYC Dept. of Parks and Recreation's community gardening program), staff from related non-profits, and researchers from The New School and Cornell University. Farming Concrete ensures that data and analysis are given back to each participating gardener at the conclusion of the year and are available digitally for those who prefer to do their own analysis. In addition, all software and data visualization tools developed for and used by the project are open source, and a toolkit is being designed to facilitate replication of the study in other municipalities.

Quantifying Urban Agriculture Yields

The economic value of community gardens and the importance they have in improving food security and community health have not yet been fully documented in academic literature. Here we summarize two recent studies that attempt to measure the value of urban agriculture, and in the Discussion we will compare their approaches to the Farming Concrete project.

In 2008 and 2009, University of Pennsylvania researchers Domenic Vitiello, Michael Nairn, and Jeane Ann Grisso, with a team of researchers, quantified the production and documented the distribution of food from community gardens and farms in Philadelphia, Pennsylvania; Camden, New Jersey; and Trenton, New Jersey (Vitiello and Nairn 2009). The team visited over 600 sites in 2008 to record which gardens were producing food, surveying each food-producing site for the square footage under production by crop (e.g., 10 square feet of tomatoes), water sources, and evidence of support organizations (Vitiello and Nairn 2009). The team surveyed 226 food producing gardens in Philadelphia, 48 in Camden, and 29 in Trenton. Data were recorded differently for small and large community gardens. In Philadelphia, at small sites, all of the area under production was recorded per crop. At larger gardens, 10% of the plots were recorded by crop (Vitiello and Nairn 2009). In both Camden and Trenton, the total area under production was surveyed. To estimate the pounds of produce per square foot, the research team selected six gardens to track harvest yields. Data from these gardens were used to estimate the yields from the other surveyed sites (Vitiello and Nairn 2009).

In 2011, the Urban Design Lab at Columbia University published *The Potential for Urban Agriculture in NYC*, in which the researchers acknowledge that "estimating potential yields is a notoriously unreliable exercise because there are many variables to consider, including environmental conditions (soil, water, sunlight, etc.) and growing techniques, not to mention what types of crops or food are being evaluated" (Ackerman 2011). The report calculates the capacity for urban crop production in New York City using average commercial crop yields from the USDA and yields recorded from biointensive farming in *How to Grow More Vegetables* by John Jeavons (2006).

METHODOLOGY

Data Collection

Farming Concrete attempts to determine the amount of food produced in New York City's community gardens by involving gardeners throughout the process. Much of the initial work involves outreach, where a core team of organizers, community gardeners, and volunteer researchers talks to community and school gardeners to sign up participants. Once a gardener agrees to participate, they collect data in one or both of two distinct phases: weighing produce throughout the season and counting plants at one to three points in the growing season.

Gardens interested in weighing produce receive a small kitchen scale and printed forms on which they record pounds per crop and the number of plants per crop for the duration of the growing season. Those interested in counting plants record the number of plants per crop and dimensions of areas under production for the entire garden using printed forms that are provided. Crops without a determinable number of plants (e.g., strawberries) are recorded by square foot coverage. Only fruits and vegetables were recorded during Year 1; herbs and fruit trees were considered beginning in Year 2. Gardeners submitted their data at the end of the season by mail, fax, email, or an online form that put their data directly into the central database.

Data Analysis

Gardeners who volunteered to share data from their harvests formed the sample group for measuring crop yields. The total weight and total number of plants weighed by crop as recorded by these gardeners facilitate the calculation of an average yield per plant. From these average yields, estimated yields were found for each garden where the quantity of plants by crop was recorded.

Total yield data were calculated on multiple scales: individual gardener, garden, borough, and citywide. Yields were monetized using prices from Whole Foods and local urban farms to account for the premium that local, organic food typically demands. Each participating garden received an individual report as well as a copy of the citywide report, both in digital and hard copy forms. An interactive, online map was developed to allow gardeners and other interested individuals to look at the results in an exploratory and visually appealing manner (harvest.farmingconcrete.org).

Outreach and Project Management

The original plan was for Farming Concrete to exist as a one-year project that would produce baseline data for food production in NYC community gardens. The research team had its first meeting in early June, 2010. Two weeks later, the first data collection forms and a scale for weighing produce were delivered to Hollenback Community Garden in Brooklyn, and a month after that, nearly 100 forms and scales were delivered to gardens across the five boroughs. In August, the project shifted focus from outreach and scale delivery to garden mapping and crop inventory, and by the end of September, 2010, had collected the first round of produce weight data from participating gardeners.

Outreach was done largely in person, using GreenThumb's garden database as a base map. This allowed the project's volunteers to meet a large number of gardeners throughout the city, training those who were interested in signing up on the spot. These face-to-face, informal meetings humanized the research process. Gardeners often showed considerable interest and excitement about the project and this led to Farming Concrete being re-conceptualized as a three-year project to develop robust data for fruit and vegetable yields in community gardens.

Year 1 was decentralized in both management and implementation. There was no paid staff, so most of those involved had other time commitments such as school and work. The project's office-space, offered in-kind by GreenThumb, was mostly avoided, opting instead for optimum productivity in the field and relying on digital communications for most of the project coordination. Aside from weekly meetings, everything was coordinated using shared Google Docs and email. Keeping an updated master spreadsheet of activities quickly became a challenge, and the need for at least a part-time staff person became clear.

Using feedback from an evaluation survey conducted at the end of the 2010 growing season, a few changes were made to Farming Concrete's methodology. Participation was distinctly categorized into two named areas to clarify the methodology: weighing produce (Harvest Kit) and crop inventory (Crop Count Kit). Gardeners could choose to participate in one or both at the start of the season. The Harvest Kit consists of a simple kitchen scale and a harvest logbook, to be kept in the garden and shared among participating gardeners. The Crop Count Kit consists of a spreadsheet with which to record an inventory of edible crops. A garden could also opt to do Crop Count more than once to account for succession planting.

With a grant from the New York Community Trust, Farming Concrete was able to hire a part-time Project Coordinator as well as six trainers. The trainers were mostly community gardeners and were responsible for training interested gardeners near where they lived. Local non-profit Just Food gave these trainers workshop education, and gardeners began training each other in citizen science methods. Another major change was that trainers only went to gardens that invited them - the project did not have the resources for on-foot outreach. The outreach strategy from Year 1 ultimately proved to be inefficient and relied too heavily on non-gardener volunteer labor to be sustained for the duration of the project. Instead, flyers were printed that doubled as postcards so that gardeners could pick up information at an event or workshop (there are many each spring, hosted by government agencies and non-profit organizations to promote and support gardening) and sign up once they had spoken to fellow garden members.

Instead of managing the status of each garden or gardener using shared spreadsheets, in 2011 Farming Concrete used open source online systems Drupal and CiviCRM to track contact information. Mailing addresses, phone numbers, and scheduled trainings were stored here to streamline the research process. A new online database for produce yield and crop inventory data was created to make data entry and analysis more efficient, and those gardeners with access to the Internet entered their data online themselves. These technologies helped those doing administrative tasks for the project save time and made it easier to stay in touch with participating gardeners.

RESULTS

A total of 67 gardens with a cumulative 1.7 acres under production were inventoried in 2010 with an estimated yield of 87,690 pounds, worth approximately $214,060. This is about 1.2 pounds and $3 per square foot. The top five crops by number of plants were tomatoes, beans, sweet peppers, calaloo, and collard greens, respectively (Table 1). The top five crops by weight were tomatoes, cucumbers, sweet peppers, Swiss chard, and collard greens, respectively (Table 2). One hundred ten (110) gardeners in 30 gardens tracked their harvests throughout the summer, some continuing through the fall. Many of these gardeners participated in Year 2.

In 2011, a total of 43 gardens participated, 35 of which were inventoried. For the 35 inventoried gardens, there was a total of 13,000 pounds of fresh produce grown on 0.94 acres, worth $47,000. This is about a third of a pound and $1.15 per square foot. The top five crops by number of plants were lettuce, tomatoes, sweet peppers, hot peppers, and cherry tomatoes, respectively. The top five crops by weight were tomatoes, cucumbers, summer squash, cilantro, and cherry tomatoes.

Table 1: Ten Most Frequently Planted Community Garden Crops, New York, NY – 2010 and 2011 (Numbers of Plants). Sixty-seven (67) gardens were inventoried in 2010. Thirty-five (35) gardens were inventoried in 2011.

2010		2011	
Crop	**Number of plants**	**Crop**	**Number of plants**
Tomatoes	7,150	Lettuce	1,524
Beans	4,732	Tomatoes	889
Sweet Peppers	3,201	Sweet Peppers	626
Calaloo	2,483	Hot Peppers	363
Collard Greens	2,439	Cherry Tomatoes	353
Okra	2,075	Bush Beans	338
Lettuce	1,964	Radish	333
Hot Peppers	1,416	Eggplant	298
Cucumbers	1,335	Calaloo	285
Swiss Chard	1,252	Collard Greens	280

Table 2: Ten Most Prolific Community Garden Crops, New York, NY – 2010 and 2011 (Pounds). Sixty-seven (67) gardens were inventoried in 2010. Thirty-five (35) gardens were inventoried in 2011.

2010		2011	
Crop	**Pounds**	**Crop**	**Pounds**
Tomatoes	29,628	Tomatoes	4,116
Cucumbers	8,322	Cucumbers	1,452
Sweet Peppers	7,843	Summer Squash	1,357
Swiss Chard	5,505	Cilantro	635
Collard Greens	5,002	Cherry Tomatoes	611
Summer Squash	4,305	Eggplant	575
Eggplant	3,838	Cabbage	478
Winter Squash	3,003	Sweet Peppers	444
Hot Peppers	2,518	Calaloo	433
Cabbage	2,319	Hot Peppers	352

DISCUSSION

As is the case with all agricultural research, these results were affected by variables such as weather, pests, and crop variety. As such, the above results are relevant only to 2010 and 2011, and only to those gardens that were inventoried. Community gardens are open public spaces, and a few participants noted that not all of their harvests could be weighed due to occasional snacks by garden visitors. In addition, some crop varieties were ignored in citywide analysis. For example, hot peppers were recorded rather than habañero and jalapeño peppers separately. More data would be necessary to extrapolate findings to community gardens citywide, including records of the area under production at each food-producing community garden as well as information about gardening methods like succession planting, as the same garden plot might have different crops in each of the four seasons. Furthermore, not all participating gardeners continued to weigh their harvests through the fall, thus decreasing our sample size. Reasons for discontinued participation included decreased motivation to participate, summer vacations, and confusion about the process for submitting data.

The differences between 2010 and 2011 data could be due to a number of variables and changes to the methodology. In 2011, the project included fruit trees and herbs for the first time, decreasing the average number of plants per square foot and affecting the pounds per square foot. It also included school gardens, which are often dormant during the summer months when school is out of session. The decrease in number of gardens inventoried was largely due to a change in outreach strategies. In 2010 volunteers who visited gardens would conduct Crop Counts themselves, whereas in 2011, Crop Counts were submitted voluntarily only by participating community gardens.

The most popular plants changed slightly from the first year to the second - while tomatoes, peppers, and cucumber remained in the top five, the types of greens changed from hardy, long-term crops like collard greens, swiss chard, and calaloo to quick-growing lettuce. This could be due to the involvement of several school gardens, however, a deeper understanding

of these changes would require a more thorough analysis of both the data and the project's participants.

It is interesting to see how New York City community gardeners compare to other recorded crop yields. For example, in 2010, participating gardeners grew just over two pounds of collard greens per plant, each of which occupies 1-2 square feet. Average USDA yields for conventional farming are 0.49 pounds per square foot (Ackerman 2011), and the low end of the range for "biointensive" farming is 0.95 pounds per square foot (Ackerman 2011, Jeavons 2006). Biointensive is the name given to the organic, high production farming techniques documented by John Jeavons in *How to Grow More Vegetables*, a commonly cited resource for intensive gardening (Ackerman 2011, Jeavons 2006). Biointensive methods are closer to what New York City community gardeners practice than large scale industrial farming. New York City gardeners also averaged 4.14 and 4.6 pounds per tomato plant in 2010 and 2011 respectively, with each plant occupying 1-4 square feet, compared with a conventional average of 0.6 pounds per square foot (USDA conventional average yields, Ackerman 2011) and a biointensive average 0.83 pounds per square foot (Ackerman 2011, Jeavons 2006). On the other hand, New York City gardeners averaged only 0.7 pounds per plant of sweet peppers in 2011, compared again with a conventional average of 0.6 pounds per square foot (USDA conventional average yields, Ackerman 2011) and a biointensive average 0.83 pounds per square foot (Ackerman 2011, Jeavons 2006).

While these numbers are not surprising, they do point to the ability of New York City community gardeners to grow some crops more efficiently (in terms of space) than conventional farmers, with yields that exceed the country's average. The results are also significant in illustrating the potential for and current capacity of many gardeners to produce a significant amount of food for themselves, their families, and their neighbors. Some grow enough to sell at local markets, for example East New York Farms! in Brooklyn sources produce from community gardeners for its farmers market. The availability of this produce, in addition to the community green space that it is grown in, can make an impact in neighborhoods where fresh produce availability is limited, of poor quality, and/or of low cultural relevance, as well as in areas where health conditions such as obesity, diabetes, and asthma are prevalent. Documenting the harvests of urban community gardeners helps to define their roles in the local food economy, particularly when the yields are monetized, as most of the production and consumption takes place in the informal economy and is thus not otherwise tracked.

The differences between urban agriculture in New York City and conventional agriculture point to a benefit of this new dataset: average yields in pounds per plant, as opposed to pounds per square foot or per acre. In New York City community gardens individuals often tend their own plots, with the result that there are usually multiple crops in each bed. Thus it is sometimes easier for a gardener to count the number of plants than it is to count the square foot coverage of each plant, especially when gardeners practice intensive growing and vertical gardening. This dataset, which includes pounds per plant for many of the city's most popular crops, is available to gardeners to use for their own purposes. Furthermore, this project has led to the creation of a methodology which can be used in future studies to obtain reliable yields for this model of agriculture.

Citizen Science and Farming Concrete

Farming Concrete uses a citizen science approach for a variety reasons, but we examine two in this section: the heterogeneous nature of community gardens and the acknowledgement of gardeners as experts for this research question.

The heterogeneous nature of community gardens requires a flexible project that respects the internal politics of community gardens. Each garden differs in management structure, population, and cultivation methods, and these affect the way the study is carried out at each site. For example, some gardens presented the idea at a membership meeting and voted before participating, whereas in other gardens a few members chose to participate on their own. Using standard scientific research methods, random gardeners would have been assigned to the project. This would have required greater resources, as researchers would have to be stationed at each garden to help weigh harvests, and it would likely have drawn resentment from those gardeners not interested in the study.

In addition, each gardener knows more about the crop varieties, harvest times, and harvest amounts from their own garden plot than anyone else, and can adapt record-keeping strategies to their own needs. As such, gardeners played an important role in shaping the study, leading to the addition of systems for measuring school gardens, crop varieties, fruit trees, herbs, and composting. Likewise, the second year's group of trainers consisted almost entirely of community gardeners, and this ensures that the study continues to be fueled by the gardeners themselves.

Rather than use estimated yields from outside of New York City (Ackerman 2011) or commercial and USDA yields, Farming Concrete used yield data recorded by New York City community gardeners, using methodology similar to that of Vitiello and Nairn (2009). The types of data collected by Farming Concrete and Philadelphia Harvest are essentially the same: actual crop yields and actual areas under production at each participating garden. In contrast, Farming Concrete records all crops at each garden rather than sampling from large gardens. Farming Concrete differs from both Philadelphia Harvest and *The Potential for Urban Agriculture in NYC* in fundamental organizational ways as well. The project is conducted outside of academic institutions, though institutions are consulted for advice. As a result of both this and the project's citizen science strategies, gardeners and researchers alike were involved in planning and implementation phases. This organizational method encouraged enthusiastic gardeners to participate not just in quantifying their food production, but in outreach as well. Multiple gardeners took part in organizing outreach to get more gardens involved in tracking their produce.

CONCLUSION

Quantifying food production in New York City's community gardens is valuable to different stakeholders for different reasons. Farming Concrete's partners – leaders in urban sustainability in both the public and private sectors – value this information as critical for building capacity for their work. For urban farmers, emergency food providers, and other entities, knowing how many pounds of food are grown every year in the city could inform and justify potential connections with community gardens as food sources and potentially give momentum to efforts to develop

new urban farms. Gardens can leverage the monetary value of their production to gain visibility, access funding, and build capacity to grow even more food. More broadly, this information can provide incentives for the preservation of existing community gardens and the creation of new ones. It can also inform new shifts in policy related to urban agriculture and expanding urban food production.

This study does not take into full account the vast spectrum of activities occurring within community gardens today. Much of the recent community gardening literature focuses on community development, and cites the role of gardens in creating a sense of community, economic opportunities, and an enhanced environment in poor, ethnically diverse neighborhoods (Saldivar-Tanaka and Krasny 2004). By focusing only on food production, we by no means intend to suggest that community gardens are only for food production, or that they should be. We believe that documenting and quantifying food production can contribute to the dialogue around urban agriculture and community garden policy and practice.

By employing citizen science techniques, Farming Concrete works directly with people who have a stake in research outcomes, as well as in how the data is used. Increasing gardener agency in both the design and the implementation of the study may improve the rates and quality of garden participation, and may contribute to a rise in similar action research projects in New York City and elsewhere. Future research could explore possible connections between citizen science, civic participation and action, community garden land tenure, food security, and urban ecology.

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